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Dr. Marshall C. Harrington
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Air Force Office of Scientific Research
Office of Aerospace Research
United States Air Force
Washington 25, D.C.

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Interim Final Report

Dear Dr. Harrington:

This letter comprises the interim final report for AF-OSR Contract AF-49 (638)-342. I shall summarize briefly work pursued under this contract up to November 30, 1962, as requested in your letter dated August 4, 1962.

In addition to the principal investigator, the following staff of the Hansen Laboratories have been supported in part by this contract: Mr. J. Allison, Research Associate; Dr. D. Baldwin, Research Associate; Mr. R. Blum, Research Assistant. The contract has also supported the visit to Stanford of Dr. L. Mestel, Cambridge University, England, during the summer of 1961; and of Professor F. Kahn of Manchester University, England, who visited Stanford briefly during the same period.

The following research topics have been studied with the help of this contract:

1) Type II and Type III Solar Radio Bursts. (P. A. Sturrock) It has been realized for some time that each of these bursts represents the excitation of plasma oscillations in the solar corona and radiation from these oscillations. It has been realized that radiation of the fundamental is due to scattering from inhomogeneities. My study has established that radiation at the second harmonic is due to the nonlinear interaction of the excited plasma oscillations. A theorem has been developed which establishes that this mechanism is more significant than that of Ginzburg and Zhelezniakov, which attributes the second harmonic to scattering of plasma oscillations on thermal fluctuations. It has been concluded that Type III bursts are due to clouds of high-energy electrons and that Type II bursts are due to electrostatic rather than magneto-hydrodynamic shock waves, plasma oscillations being excited by electrons accelerated in the shock front. This explains the "herring-bone" structure of some Type II bursts. This interpretation, together with the concept of "resonant Cerenkov radiation", which occurs when the particle velocity is equal to the group velocity of the excited waves, explains the splitting observed in Type II bursts.

2) Irreversible Processes in Conservative Systems. (P. A. Sturrock)
Discussion of the phenomenon of "incoherent backscatter" and of similar phenomena in plasma physics requiresclose understanding of "Landau damping" in plasmas, and of the relevance of Nyquist's theorem to plasma phenomena. In order to contribute to this understanding, a simple dynamical model of a plasma, as an assembly of harmonic oscillators, was investigated. This simple model exhibits the irreversible phenomena referred to, and their inter-relationship is clearly demonstrated.

3) Generation of Radio Noise in the Vicinity of the Earth. (P. A. Sturrock)
This study was an attempt to classify various types of radio noise which might be generated in the magnetosphere of the earth by listing possible energy sources, and possible mechanisms for conversion of this energy into electromagnetic form. In the course of this work, the concept of "generalized two-stream instability" was established, and that of "resonant Cerenkov radiation". These concepts are relevant to discussion of the excitation of magnetohydrodynamic, whistler, and other waves by streams of charged particles.

4) Radio Bursts from Jupiter. (P. A. Sturrock)
It is believed that these bursts may be attributed to the velocity-anisotropy instability of a plasma in a magnetic field which gives rise to radiation at the electron cyclotron frequency. Preliminary estimates of the magnitude of this radiation have been encouraging. The theory seems to explain the sharpness of the radiation, its polarization, and drifts in frequency. It appears also to fit the known relationship of this noise to solar activity.

5) Interaction of the Geomagnetic Field with the Solar Corpuscular Radiation. (R. Blum)
The mathematical problem of determining the structure of the interface between the magnetosphere and the solar wind has been investigated. A procedure has been developed which comprises two parts: First, an approximate form of the interface is derived by a colocation technique; second, the estimate of the interface and magnetic field so obtained is improved by relaxation calculation. The method has been tested on two-dimensional models and gives results in good agreement with known analytical solutions. The application of this technique to the three-dimensional problem is now in hand.

6) The Solar Magnetic Field. (L. Mestel)
During his visit to Stanford, Dr. Mestel further developed his theory of the solar magnetic field which is notable in that it yields the observed equatorial acceleration of the sun. He also investigated the mechanism of the generation of toroidal magnetic fields in stars by thermal pressure and concluded that this mechanism is of no significance.

7) Study of Experimental Reproduction of Type III Radio Bursts. (J. Allison and D. Baldwin)
The possibility of setting up an experimental system to

study the Cerenkov excitation of plasma oscillations and radiation from these plasma oscillations has been studied. It was concluded that this experiment is possible if one combines a) a lithium ion gun in the kilovolt range; b) a nanosecond beam-switching unit; and c) a low-density quiescent plasma of number density about 10^7 electrons /cm^3. It was concluded that these requirements could be met but the experiment would be a difficult undertaking.

8) The Solar Wind. (D. Baldwin)
The calculations of Chamberlain on the solar wind have been re-examined, replacing the assumption that the wind velocity is zero asymptotically by the velocity observation made by Explorer X. Preliminary calculations show that this revision gives much better agreement with the observed densities near the sun and near the earth. A modified set of equations has been developed to allow for the different thermal conductivities of the electron gas and ion gas, and of the weak thermal exchange between the two.

The following talks have presented work done under this contract:

Group Velocity and Its Significance in Plasma Problems.
California Institute of Technology, October 1960.

Irreversible Phenomena in Plasmas.
Princeton University, February 1961.

Generation of Radio Noise in the Vicinity of the Earth.
URSI Conference, Washington D.C., May 1961.

Type II and Type III Radio Bursts.
Varenna, Italy, June 1961.

Determination of the Interface Between the Solar Wind and the Earth's Magnetic Field. (R. Blum)
URSI Conference, Washington D.C., May 1962.

Cosmical Electrodynamics. (L. Mestel)
A series of seminars on this subject given at Stanford University during the summer of 1961.

Nonlinear Theory of Waves in Plasmas.
Varenna, Italy, July 1962. (This included discussion of solar radio bursts.)

Nonlinear Wave Theory in the Problem of Solar Radio Bursts.
University of Michigan, Ann Arbor, September 1962.

The following reports and articles have been or are being published:

"Irreversible Processes in Conservative Dynamical Systems"
Microwave Laboratory Report M.L. 784, January 1961.

"Generation of Radio Noise in the Vicinity of the Earth"
Microwave Laboratory Report M.L. 840, September 1961;
also Journal of Research of the Nat. Bur. of Standards -D. Radiopropagation 66D, 153 (1962).

"Spectral Characteristics of Type II Solar Radio Bursts"
Nature, 192, p. 58 (1961).

"Type II and Type III Solar Radio Bursts"
to be published in the (much delayed) Proceedings of the Conference on Cosmic Radiation, Solar Particles and Space Science; Varenna (1961).

"Nonlinear Theory of Waves in Plasmas"
to be published in the Proceedings of the Conference on Plasma Physics, Varenna (1962).

"Solar Corpuscular Radiation and the Geomagnetic Field"
(R. Blum: to be published in Icarus).

"On the Thermal Generation of Toroidal Magnetic Fields in Rotating Stars" (L. Mestel with I. W. Roxburgh)
Astrophysical Journal, 136, 615 (1962).

Since much of the work carried on under this contract has not yet reached the stage of final publication, I am very glad that Grant AF-OSR-62-326 provides continued support which will enable me to continue the projects listed in this letter.

Sincerely yours,

P A Sturrock

P. A. Sturrock
Professor of Engineering Science
and Applied Physics

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